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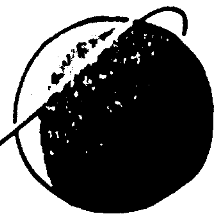


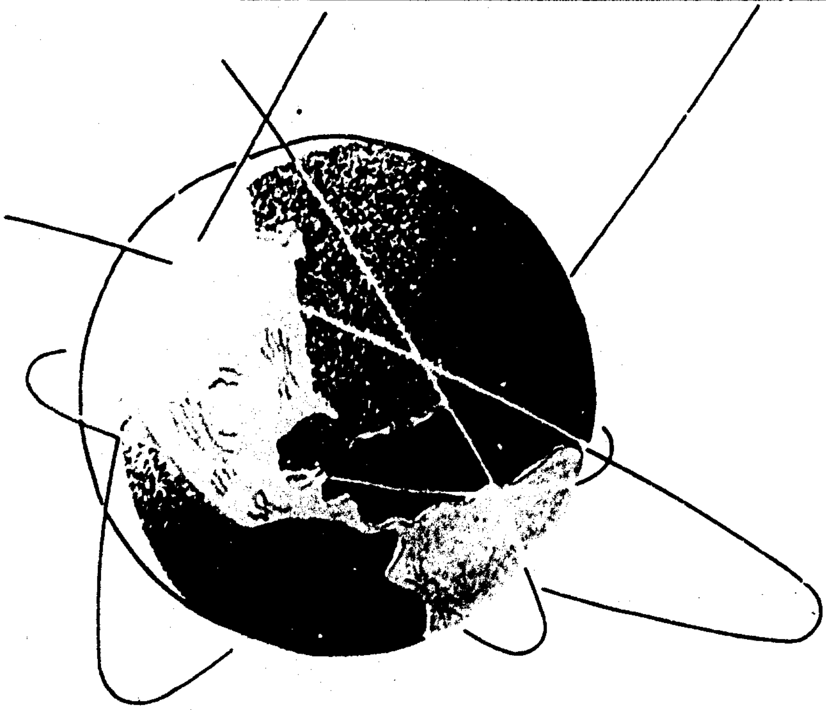
GROUND IMPACT SHOCK MITIGATION

HOWITZER 105MM M2A1

BY

DAVID G. WIEDERANDERS

EMRL TR 1020 JULY 1967



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ENGINEERING MECHANICS RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS · AUSTIN, TEXAS

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TR 1020

GROUND IMPACT SHOCK MITIGATION
HOWITZER 105mm M2A1

by

David G. Wiederanders

QUARTERMASTER RESEARCH AND ENGINEERING COMMAND
AIRDROP ENGINEERING DIVISION

Project No. 1F121401D195

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ENGINEERING MECHANICS RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS

Austin, Texas

PREFACE

This report is the third in a series of four dealing with high velocity airdrops of selected military vehicles. High velocity in this case means an impact velocity of 50 fps or higher. The other three reports in the series are entitled

Ground Impact Shock Mitigation M151 Utility Vehicle (Jeep)

Ground Impact Shock Mitigation Cargo Truck, 3/4-Ton M37

Ground Impact Shock Mitigation Cargo Trailer M101, 3/4-Ton

Each of these vehicles were studied previously under Contract DA 19-129-QM 1383 with the Natick Laboratories. However, in these earlier studies, impact velocities were limited to 30 fps and the design acceleration was 16g. These limitations were imposed by airdrop operational procedures at that time. Results of these earlier studies were published in a series of reports entitled,

Fragility Studies

Part I Utility Truck 1/4-Ton (Jeep)

Part II Cargo Truck M37 3/4-Ton

Part IV Cargo Trailer M101 3/4-Ton

In the investigation described in this report, the only limitation on the impact velocity was the maximum available drop height at the drop facility. For the howitzer, this height was 46 feet. From this maximum height, an impact velocity of 54 fps was developed. The only limitation on the design acceleration was that it not be so high as to damage the vehicle. The maximum practical value was 30g. To obtain higher accelerations, a stronger cushioning material, or an impractical cushioning area had to be used. No drive-on, drive-off capability was designed into the cushioning system since this was intended to be only a feasibility study. However, since the howitzer must be towed, getting it off the cushioning system after a drop presents no serious problem.

E. A. Ripperger
Director
Engineering Mechanics Research Laboratory
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July 1967

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ABSTRACT

The 105mm Howitzer supplied to this laboratory by the Army Tank and Automotive Command through arrangements made with Natick Laboratories has been dropped five times at impact velocities up to 54.4 fps, and at design accelerations as high as 30g. The initial modifications of the vehicle in preparation for the drop series and the design criterion for this test series are presented along with a description of the cushioning system used and the damage sustained in each drop.

It is concluded that this vehicle can be dropped at impact velocities up to 50 fps without any damage, if a properly designed cushioning system is used.

INTRODUCTION

Twenty-five feet per second has been the nominal design impact velocity for the air drop of equipment and supplies for several years. It has been shown, however, by Turnbow and Steyer[1]* that the cost of air drop can be reduced appreciably by using a higher impact velocity. This saving results from the use of relatively inexpensive paper honeycomb to dissipate the energy, rather than the large expensive parachutes required to achieve the 25 fps impact velocities. In addition, a higher impact velocity reduces the dispersion of the dropped material, increases the accuracy of the drop insofar as hitting the target area is concerned, and, because of the reduced time that the equipment is in the air, reduces the danger from possible enemy action.

In theory, at least, it is possible to cushion a vehicle so that it will survive an impact of any velocity, but there are other considerations. For example, the space available in aircraft is limited. This obviously places a limit on the impact velocity that can be sustained because the volume of cushioning material increases with the square of the impact velocity. In addition, the stability of the cushioning system becomes a serious problem as the height of the cushioning stack increases.

In order to study some of the practical problems of cushioning vehicles against high impact velocities; to discover some of the hidden problems which might exist; the program of drops of the 105mm Howitzer, which is reported here, was undertaken.

The primary objectives of this investigation have been

1. to verify that the vehicle could be successfully dropped at impact velocities as high as 50 fps,
2. to determine the maximum design acceleration that could be used for such a drop,
3. to work out the essential details of a prototype cushioning system, and
4. to observe the damage susceptibility of the vehicle.

The collection of data regarding the damage susceptibility of certain specific vehicles is but one phase of the research program which is intended eventually to put the design of cushioning systems for the airdrop of equipment on a firm engineering

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* Superscript numerals indicate references listed at the end of the report.

basis. However, a standard cushioning system applicable to all vehicles is not feasible. Hence, each vehicle must have its own system, and although these differ somewhat in detail, they should all conform to the basic principles of cushioning design as those principles are now understood.

PROCEDURE

The approach employed was to make the first drop with a 20g design acceleration and a drop height of 10 feet, and then in successive drops, to gradually increase these values as seemed warranted by the results of previous drops.

The vehicle used for this test series was a 105mm Howitzer, M2A1 and associated carriage assembly M2A2, supplied by the Army Tank and Automotive Center under arrangements made through the U. S. Army Natick Laboratories.

It was dropped in the "as-received" condition except for the following modifications:

1. Lifting wheel plates installed.

2. Extension bar assembly installed.

3. Protective covering installed over sight mount and elevation gear assemblies.

4. Accelerometers installed on each trail in the same vertical plane as the C.G. of the vehicle and on the left trail just in front of the towing pintle.

These modifications were made to provide lifting points, to reduce the overall length of the system as much as possible, by putting the barrel in the recoil position, to protect those areas which might be damaged by the lifting shackle, and to provide acceleration data during impact, respectively.

Drop Program

As previously indicated, the first drop was from a height of 10 feet with a design acceleration of 20g. In subsequent drops, both the height and design acceleration were increased as seemed warranted by the results of the previous tests. This procedure was followed so an effective cushioning system could be designed and tested at lower impact velocities before relying on the system at high impact velocities and accelerations. By following this procedure, it was expected that the maximum amount of information would be obtained for the vehicle before it was damaged so much as to make further drops impractical. A drop height of 46.3 feet and a design acceleration of 30g were reached in the final drop of the series with no significant damage to the vehicle being detected during the entire program.

Problems Encountered

The main problem encountered during this test series was the lack of sufficient area forward of the C.G. to allow for cushioning systems in which the moments of the cushioning forces about the C.G. of the vehicle could be balanced. To overcome this difficulty, a relatively complex loadspreader was used. This spreader, which was attached to the bottom of the slide assembly as shown in Fig. 1, allowed a cushioning stack to be placed several feet forward of the C.G. thereby providing the additional moment required to put the system in rotational equilibrium during crushing.

The area directly under the pivot point of the Howitzer assembly was the source of another difficulty. This area is the point of greatest mass concentration in the weapon. To provide sufficient area for adequate cushioning at that point, it was necessary to design a loadspreader that would contact all the structural members with sufficient strength to transfer the cushioning force to the weapon assembly. Dimensional sketches of these loadspreaders are found in Fig. 2.

Lifting Rig

The Howitzer weapon system used for this test series was rigged for drop by attaching lifting plates and shackles to each of the wheels and installing protective wrappings around each of the trails just behind the carriage locking studs. To facilitate the lifting and leveling of the system, chains were attached to one end of each of four slings, one of the chains was passed either through the lifting shackles or around the protected trails and hooked back on itself. This allowed for quick adjustment of the lifting rig to achieve a level attitude of the system.

Each of these slings was attached to a large lifting shackle which was engaged by a helicopter hook. This hook was released for the drop by the Fastax-Camera timing control. The complete lifting rig is shown in Fig. 3.

Platform

An 8×16-ft. plywood platform was designed and built, essentially to the specifications for the combat expendable platform described in TM 10-500-19-2. This platform was used for the seven drops of the test series involving the M37 cargo truck and for the five drops of the 105mm Howitzer. The platform performed very well and has been damaged only slightly by the twelve

Fig. 1 Front Load Spreader

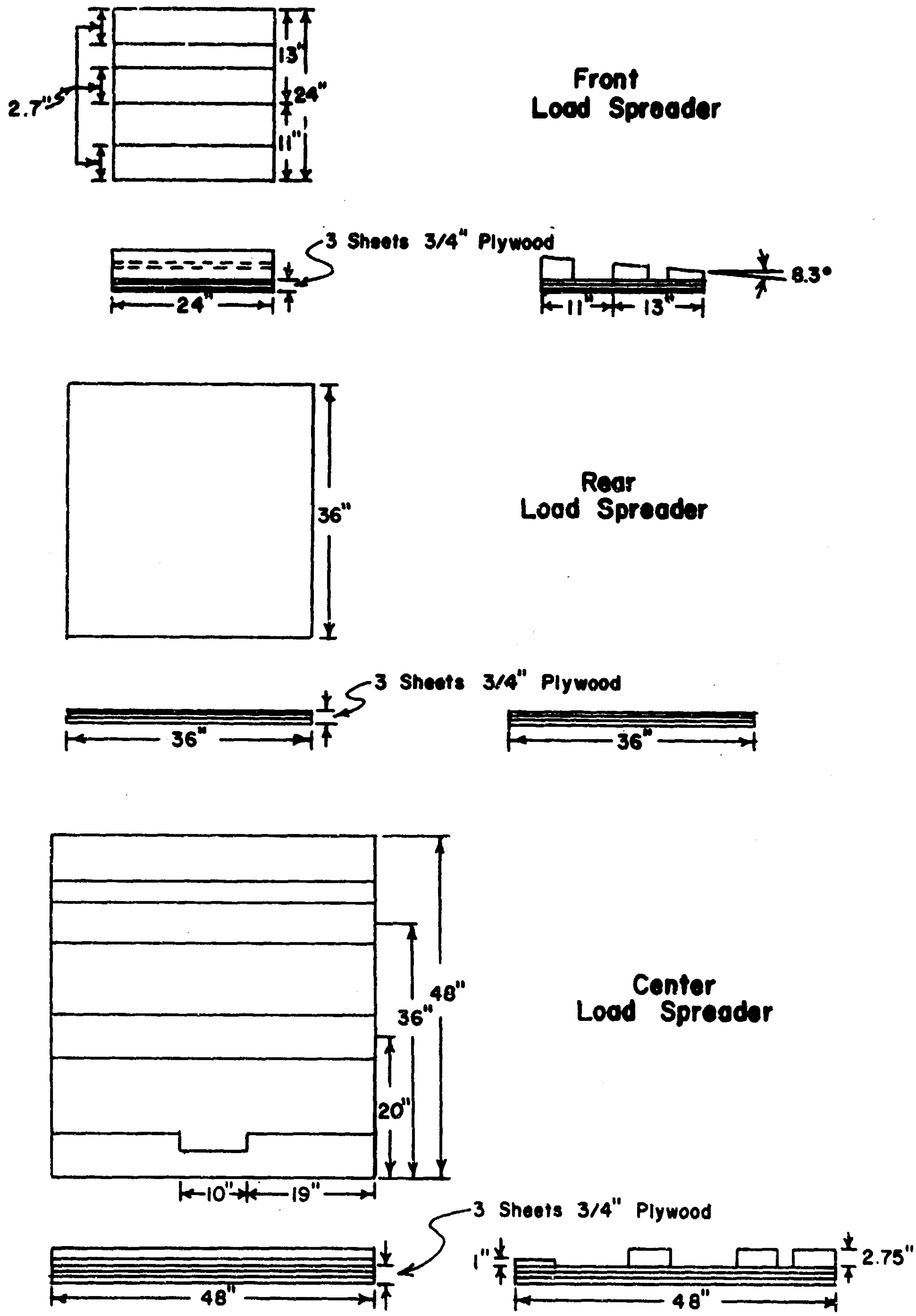
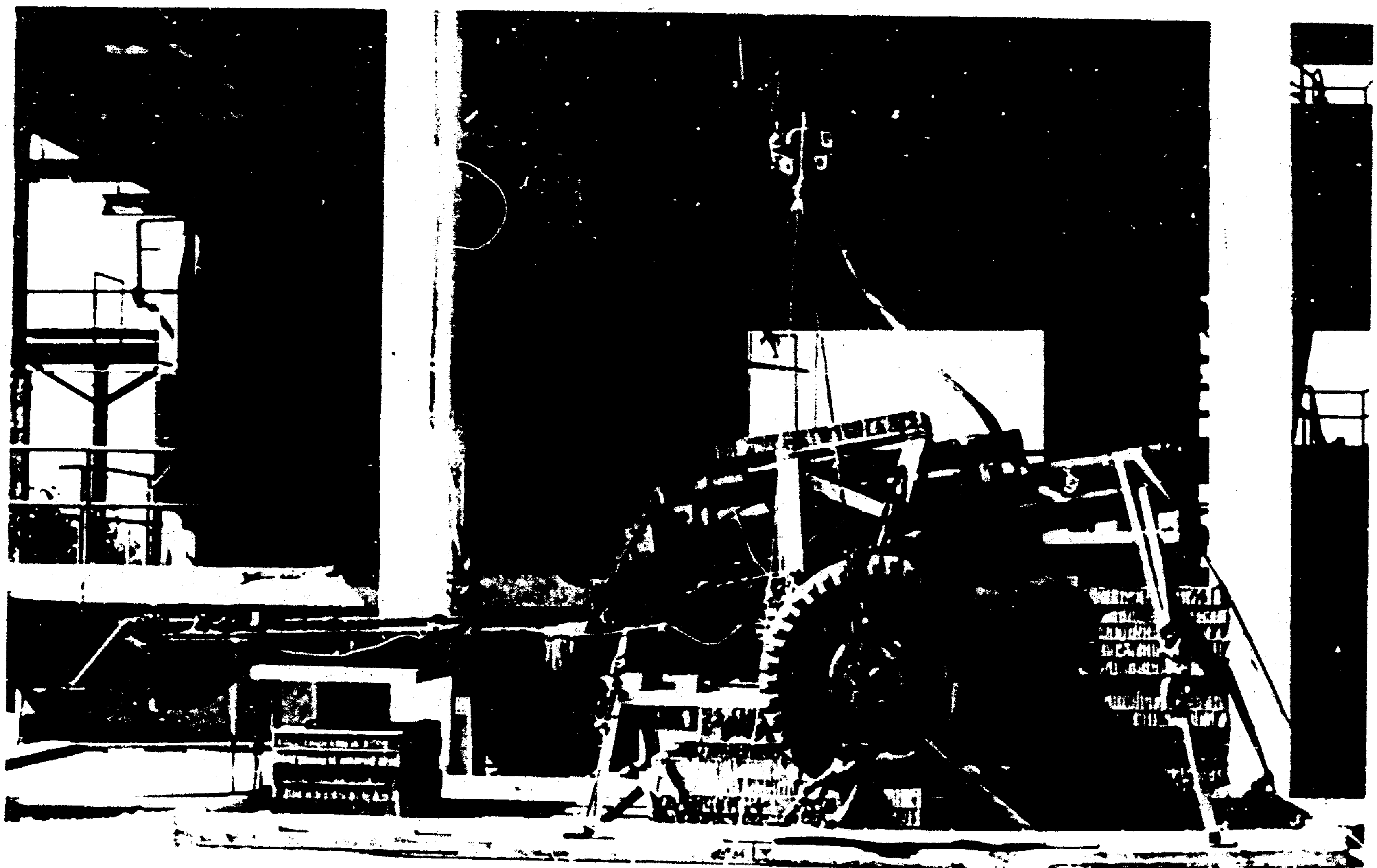


Fig. 2 Load Spreaders for the 105mm Howitzer M2A1



[illegible] Rigging for Lifting the System drops in which it was used.

Honeycomb

The cushioning material used throughout this series was 80-0-1/2 paper honeycomb purchased directly from the manufacturer. A honeycomb evaluation test series involving stacks in excess of 12 inches in height provided the values of average crushing stress and energy dissipation characteristics used to design the cushioning system. These values were found to be smaller than the values obtained for single pads because the uniformity of crushing decreases as the stack height increases. The average crushing strength was determined to be 6430 lb/ft^2 and the energy dissipated was 4500 $ft\text{-}lbs/ft^3$.

Instrumentation

Accelerometers were mounted on the system in the following positions: one on each trail directly on line with the C.G., and one on the left trail directly forward of the towing pintle.

In addition to acceleration records which were recorded by both an oscillograph and magnetic tape system, high-speed motion pictures were made of all drops. These pictures were studied to see how the cushioning system performed and for clues as to what changes should be made to improve the performance of the system. Prior to each drop, and at the completion of each drop, documentary photographs were also made. After each drop, the Howitzer was carefully examined for any visible damage and for indications of possible future problem areas.

SUMMARY OF DROP PARAMETERS AND DAMAGE OBSERVED

H-105-1; Height 10 ft.; Acceleration 20g.

This drop was made using a cushioning system design based on the measured weight distribution of the weapon in the recoil position. It is a five-point cushioning system with stacks placed under the C.G., under the trails, under the front end of the barrel sleigh, and under each of the wheels. The buildup stacks were designed so that the trails were level at impact and remained so throughout crushing. The given weights of the tipping parts of the cannon were used to locate the C.G. of these parts independently of the carriage assembly. This was done so that the reactions at the supporting points could be found. The cushioning system was then designed to subject the sleigh-locking studs to a 4000 lb. force at a design acceleration of 20g. The remaining energy at impact, due to the tipping parts, was dissipated by the front crushing stack or transmitted through the pivot point to the center cushioning stack.

The drop went as expected with all stacks crushing uniformly to 65 percent. See Fig. 4. No damage could be detected after the drop.

H-105-2; Height 20 ft.; Acceleration 30g.

The second drop of the 105mm Howitzer was made using a design calculation of 30g but still allowing only a 4000 lb. force to be transmitted through the locking studs of the sleigh assembly.

Loadspreaders were used under the wheels for this drop to more evenly distribute the cushioning force of the wheel stacks at impact. This system worked well and was used for the remainder of the test series.

The system crushed uniformly to 65 percent at impact. There was no damage to either the Howitzer or carriage assembly.

H-105-3; Height 30 ft.; Acceleration 30g.

This drop was made to test the cushioning system used in H-105-2 at the higher impact velocities of the 30 ft. drop.

The system crushed evenly to 60 percent on initial impact, but after rebound, the front stack was crushed an additional 10 percent. The wheel stacks both crushed slightly to the inside of the stack.

Fig. 4 System during H-105-1

There was no damage to the weapon or carriage from the drop or the uneven crushing. It was observed that the cannon rebounded slightly to the left side after impact. This was later found to be due to uneven tire pressure rather than an unbalanced cushioning system and was corrected before the last drop of the series.

H-105-4; Height 40 ft.; Acceleration 30g.

This drop was made from a height of 40 ft. in accordance with the test program to provide an impact velocity of 50.8 fps.

The same cushioning system used for H-105-3 was used for this drop with the only modification being the additional drop height. The system impacted flat and crushed uniformly to 60 percent.

There was no damage to the vehicle as a result of the drop or rebound. The ruggedness of this Howitzer and its mounting are sufficient, it appears, to justify a higher design acceleration. Further investigation must be made, however, into the problems higher accelerations may bring before a firm recommendation, either for or against the system, can be made.

H-105-5; Height 46.3 ft.; Acceleration 30g.

The same cushioning system used for the previous two drops was used with modifications being made for the additional drop height.

The system performed well, crushing uniformly to 65 percent. No damage was observed after the drop.

The cushioning system used for this drop is shown before and after the drop in Figs. 5 and 6. Although the cushioning system performed very well, it cannot be considered the ultimate design for the vehicle. The effectiveness of the system depends heavily on the use of a system of loadspreaders. Although the design of these loadspreaders is not overly complex, it may not be feasible to use such spreaders in an actual airdrop situation. However, since this test series was a feasibility study rather than the development of an ultimate system suitable for field use, no attempt was made to refine the design of the loadspreader system. With the prototype system shown in Fig. 7 and Table 1 as a guideline, the development of a system suitable for field use should not present significant difficulties.

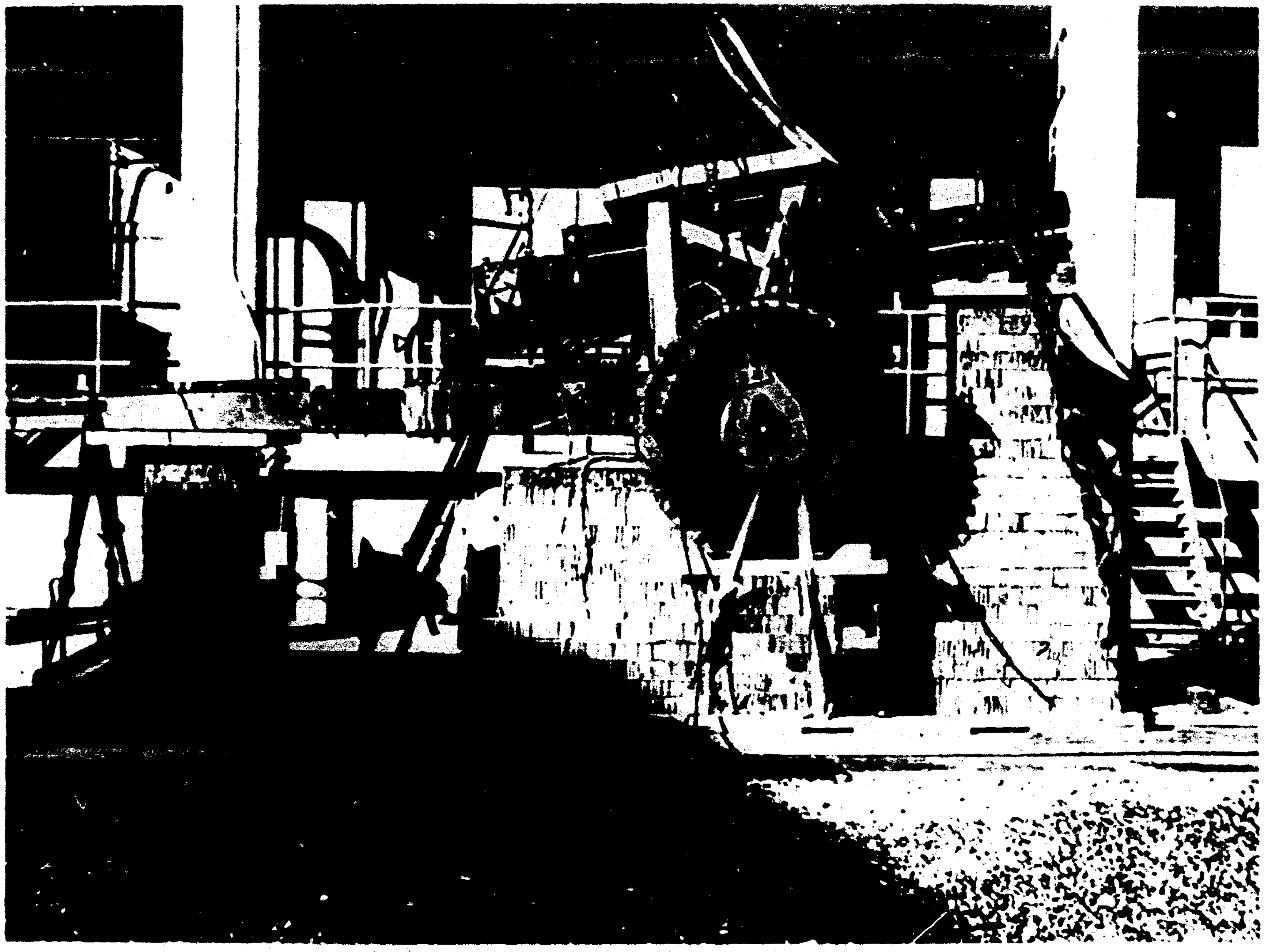


Fig. 5 Cushioning System before H-105-5

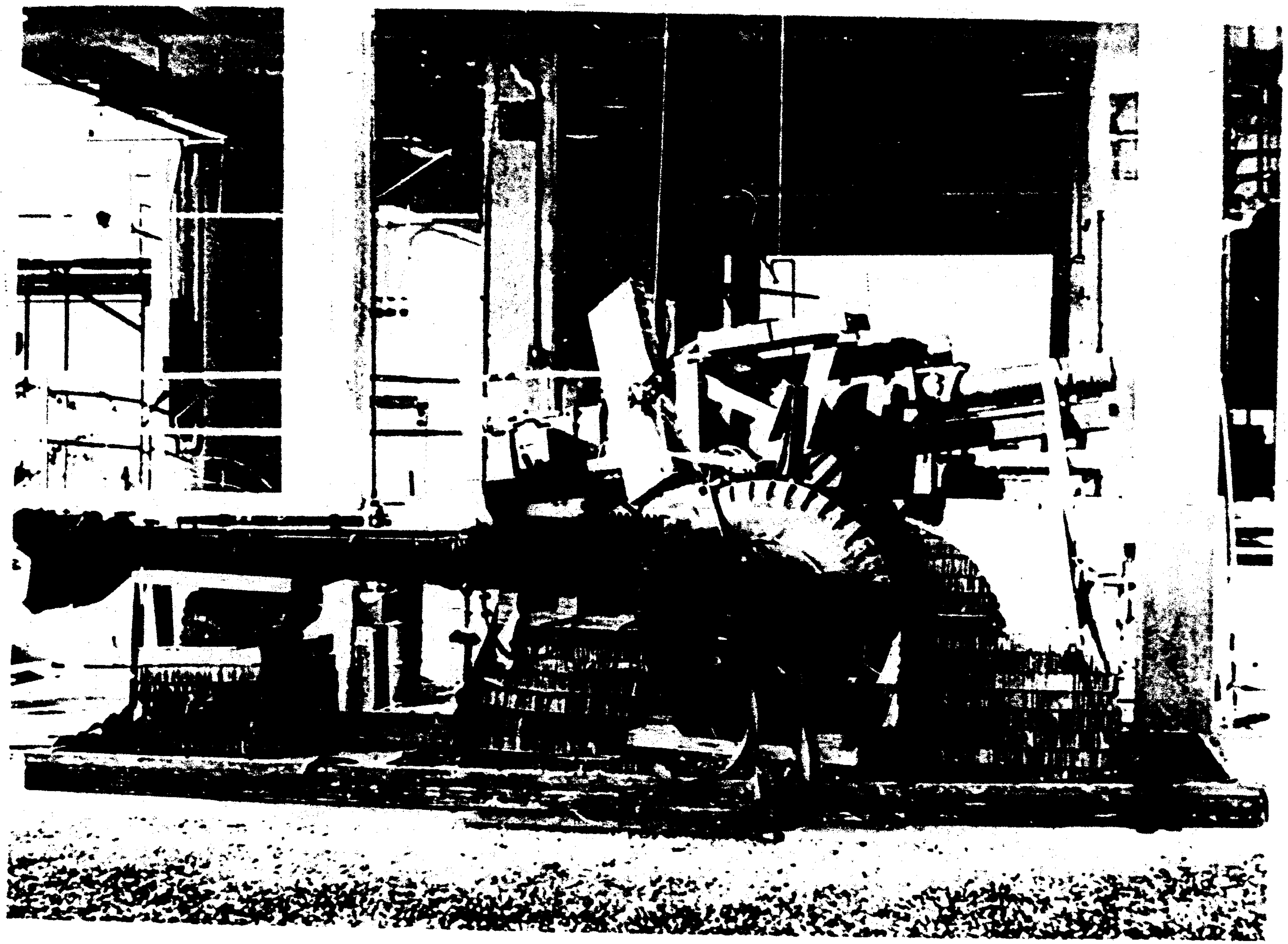


Fig. 6 System after H-105-5

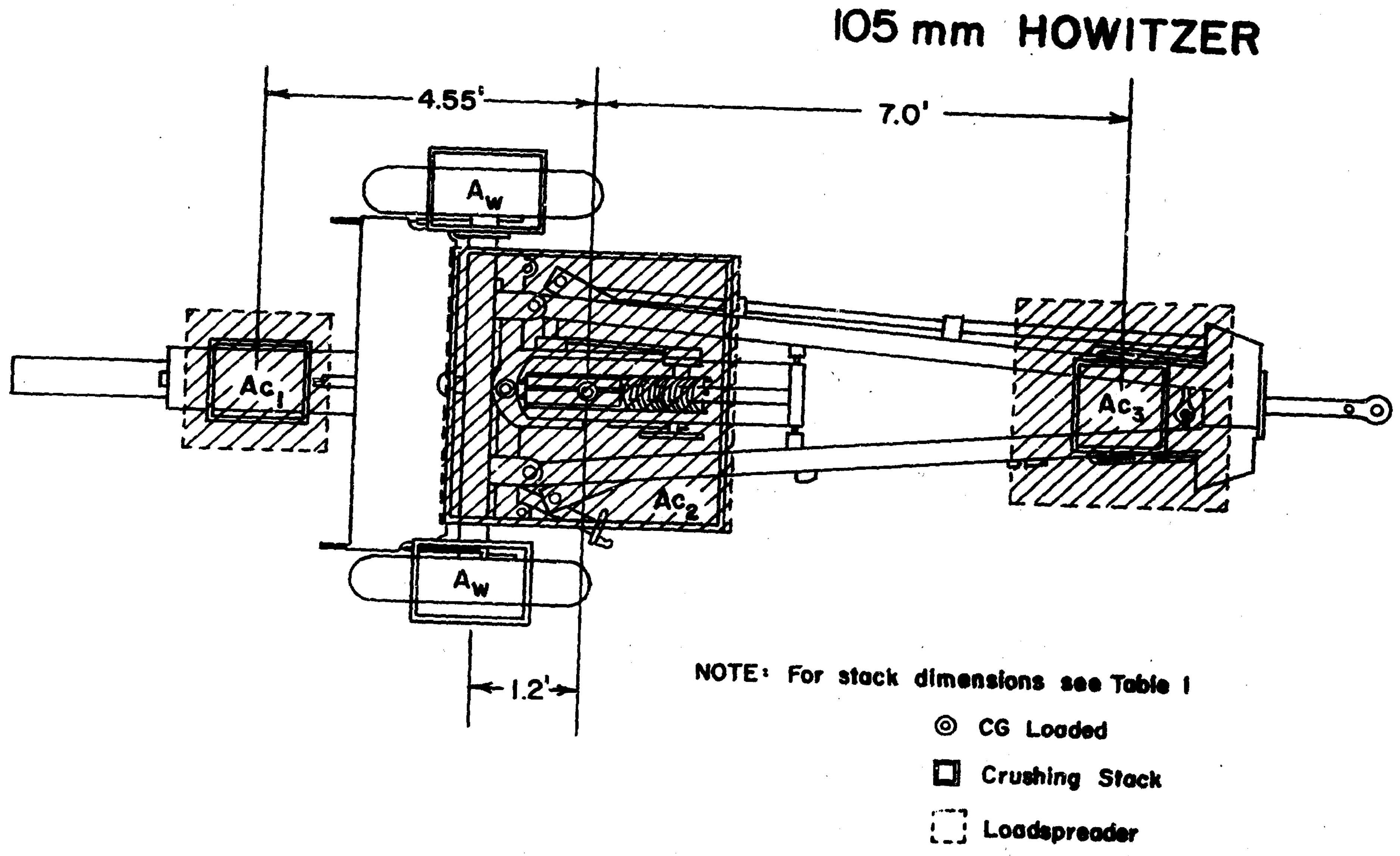


Fig. 7 Cushioning Stack Placement for H-105-5

TABLE 1

Drop H-105-5

Position	Stack Area	Dimension	Height
Ac_1	1.68 ft^2	1.2' × 1.4'	24 in.
Ac_2	15.56 ft^2	4.0' × 3.9'	24 in.
Ac_3	1.77 ft^2	1.3' × 1.36'	24 in.
A_w	1.95 ft^2	1.62' × 1.2'	24 in.

Total height of system including cushioning stacks 86 inches

The Howitzer and carriage assembly was examined thoroughly after this drop to be certain that no damage was overlooked. No sign of any damage that could be attributed to the five drops was found.

Average accelerations and peak accelerations for all the drops of the series are shown in Table 2. In general, the measured average acceleration is less than the actual design acceleration. This phenomena has been observed in previous studies and is considered to be due to the flexibility of the vehicle structure which actually provides some shock mitigation for itself. One might expect that for a rigid vehicle such as this weapon, the design and the average accelerations should be much more nearly the same than they are for the less rigid vehicles. This did seem to be reflected in the measurements but the results are not conclusive.

In Table 2, Column 8, the integral of the acceleration record is shown. For valid acceleration measurements, this integral should correspond to the impact velocity shown in Column 7. The discrepancies between the impact velocity and the acceleration integration are due mostly to the difficulty in determining just where to stop the integration. Consequently, the acceleration measurements are considered valid.

Drop Number	Area	Height-ft	Design Accel.	Peak Accel.	Ave. Accel.	Impact Vel. $\sqrt{2gh}$	Vel. Change $\int adt$
H105-1-66	Rear	10	20	28.1	12.0	25.4	29.0
	(CG) Right	10	20	24.4	13.8	25.4	27.4
	(CG) Left	10	20	25.0	14.8	25.4	27.1
H105-2-66	Rear	20	30	38.4	21.6	35.9	37.9
	(CG) Right	20	30	35.8	21.2	35.9	39.1
	(CG) Left	20	30	30.6	20.7	35.9	35.4
H105-3-66	Rear	30	30	48.6	16.1	43.8	No Record
	(CG) Right	30	30	45.3	18.7	43.8	48.6
	(CG) Left	30	30	42.8	20.8	43.8	45.6
H105-4-66	Rear	40	30	47.6	29.2	50.78	56.0
	(CG) Right	40	30	46.2	25.2	50.78	50.6
	(CG) Left	40	30	46.1	23.4	50.78	56.25
H105-5-66	Rear	46.3	30	No Record	No Record	54.4	No Record
	(CG) Right	46.3	30	46.2	25.7	54.4	59.3
	(CG) Left	46.3	30	46.2	26.1	54.4	59.1

Table 2. Acceleration Data for 105mm Howitzer Drop Series

CONCLUSIONS

1. The 105mm Howitzer weapon system can be dropped from a height of 50 feet to land with an impact velocity of 57 fps using essentially the same techniques used for dropping at 25 fps.

2. A cushioning system designed for 30g average acceleration provides adequate protection for the vehicle. This design acceleration could be used even at low-velocity drops to reduce the required stack heights.

3. There is evidence gathered from the test series that the 105mm Howitzer is of rugged enough design to be dropped using a cushioning system designed for an impact acceleration of 40g. There is, however, insufficient information available to reach a definite conclusion at this time.

4. By redesigning certain parts of the carriage assembly, the problem of insufficient area for cushioning without a loadspreader could be largely reduced.

5. Although it appears from the results of this series of drops, and of others that have been made, that vehicles can be safely and economically dropped at impact velocities in excess of 50 fps, it is desirable to drop a prototype vehicle of each type, under controlled conditions to determine possible sources of weakness or other problem areas, and to develop the details of the cushioning system for the particular vehicle under consideration.

6. In the preparation of a rugged, rigid vehicle such as the 105mm Howitzer for airdrop, greater attention needs to be paid to tire pressures than is necessary for the more flexible, sprung vehicles. Equal tire pressures are needed if undesirable rebound characteristics are to be avoided.

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2. Wiederanders, D.G., W.L. Guyton and E.A. Ripperger, *Ground Impact Shock Mitigation, Cargo Truck, 3/4-Ton M37, TR 1011*, Engineering Mechanics Research Laboratory, The University of Texas, Austin, 1966.

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It is concluded that this vehicle can be dropped at impact velocities up to 50 fps without any damage, if a properly designed cushioning system is used.

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